Multi-Lepton Events and Doubly-Charged Higgs Production at HERA

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MULTI-LEPTON EVENTS AND DOUBLY-CHARGED HIGGS PRODUCTION AT HERA

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Multi-lepton production at high transverse momentum is investigated by the H1 Collaboration in e^+p and e^-p collisions recorded at HERA until the end of 2005, corresponding to an integrated luminosity of 275 pb^{-1}. All event topologies involving electrons and muons are analysed. Di-lepton and tri-lepton event yields are found in general good agreement with the Standard Model predictions, dominated by γ-γ interactions. In e^+p collisions events with leptons of high transverse momenta are observed in a domain where the Standard Model prediction is low. Based on these topologies, a search for single production of doubly-charged Higgs bosons ($H^{\pm\pm}$) decaying into a high mass pair of same charge leptons is performed. No evidence for doubly-charged Higgs production is found and mass-dependent upper limits on the Yukawa couplings of the $H^{\pm\pm}$ to ee, $e\mu$ and $e\tau$ pairs are derived.

1. Muti-lepton event production

Within the Standard Model (SM) the production of multi-lepton events at high transverse momentum in ep collisions mainly proceeds via photon-photon interactions[1]. Precise cross-section measurements of both electron (e) and muon (μ) pair production at high transverse momentum (P_T) have already been performed by the H1 collaboration using the HERA I data[2,3]. At large di-electron masses, an excess of events was observed in both the di-electron and tri-electron samples[2]. The present analysis extends our previous measurements to the $e\mu$ and $e\mu\mu$ topologies and uses a higher integrated luminosity, combining new HERA II data taken in e^+p collisions ($\mathbb{L}$ = 52 pb^{-1}) and in e^-p collisions ($\mathbb{L}$ = 105 pb^{-1}) during the years 2003–2005 with the HERA I data sample from 1994–2000 ($\mathbb{L}$ = 118 pb^{-1}).

The multi-lepton selection requires at least two central ($20^o < \theta < 150^o$) lepton candidates (e or μ) of which one must have $P_T > 10$ GeV and the other $P_T > 5$ GeV. Additional e candidates are identified in the detector with an energy above 5 GeV in the range $5^o < \theta < 175^o$. Additional muons with $P_T > 2$ GeV in the range $20^o < \theta < 160^o$ are also looked for. The selected events are classified as ee, $\mu\mu$, $e\mu$, eee and $e\mu\mu$ as function of the number and flavours of the identified

[†] On behalf of the H1 Collaboration.

leptons. The observed event yields are given in Table 1. They are in good agreement with the SM expectations.

Table 1. Observed and predicted event yields for the multi-lepton samples. The SM predictions add contributions from the signal (Pair Production) and background (Neutral Current and Compton) processes. The errors on the predictions include model uncertainties and experimental systematic errors added in quadrature.

H1 Preliminary 275 pb^{-1} (1994–2005)

Selection	Data	SM	Pair Production	NC-DIS + Compton
ee	266	261 ± 37	217 ± 23	44 ± 22
$\mu\mu$	113	112 ± 21	112 ± 21	—
$e\mu$	137	136 ± 21	83 ± 6.5	53 ± 16
eee	52	52 ± 6	52 ± 6	—
$e\mu\mu$	63	67 ± 10.5	67 ± 10.5	—

Figure 1 shows the distribution of the scalar sum (ΣP_T) of P_T of all identified leptons for the e^+p, e^-p and combined data samples. For $\Sigma P_T > 100$ GeV 4 events are observed while 1.1 ± 0.2 are expected in overall. These four data events correspond to the three high mass *ee* events observed in the HERA I data[2] and to one new $e\mu\mu$ event observed in the HERA II data. All events with $\Sigma P_T > 100$ GeV have been recorded in the e^+p collisions.

2. Search for doubly-charged Higgs

Doubly-charged Higgs bosons ($H^{\pm\pm}$) appear in various extensions of the SM in which the usual Higgs sector is extended by one or more triplet(s) with non-zero hypercharge[4]. The Higgs triplet(s) may couple to lepton fields via Yukawa couplings which are not constrained to be small since they are not involved in the mass generation. A non-vanishing coupling of a doubly-charged Higgs to an electron-lepton pair would allow its single production in *ep* collisions at HERA. With unpolarized incident beams the production is insensitive to the helicity structure of the Yukawa couplings. The present analysis[5] investigates $H^{\pm\pm}$ decays into *ee*, $e\mu$ and $e\tau$ pairs using the unpolarized HERA I data.

Searches in the *ee* and $e\mu$ channels are based on published analyses[2,3]. The $e\tau$ channel is investigated on a subset of the HERA I data ($\mathbb{L}$ = 88 pb^{-1}) in the phase space $P^{e,\tau}_T > 10$, 5 GeV and $20^o < \theta_{e,\tau} < 140^o$, considering all possible e, μ and hadronic decays of the τ lepton. After the final Higgs selection criteria no significant excess over the SM expectation is observed in the data. Figure 2 shows the upper limits derived on the $H^{\pm\pm}$ production cross sections times decay branching ratio, together with the corresponding limits on the Yukawa couplings h_{ee}, $h_{e\mu}$ and $h_{e\tau}$ obtained by assuming that one single coupling dominates. Bounds from the LEP[6] and TEVATRON[7] experiments are also shown.

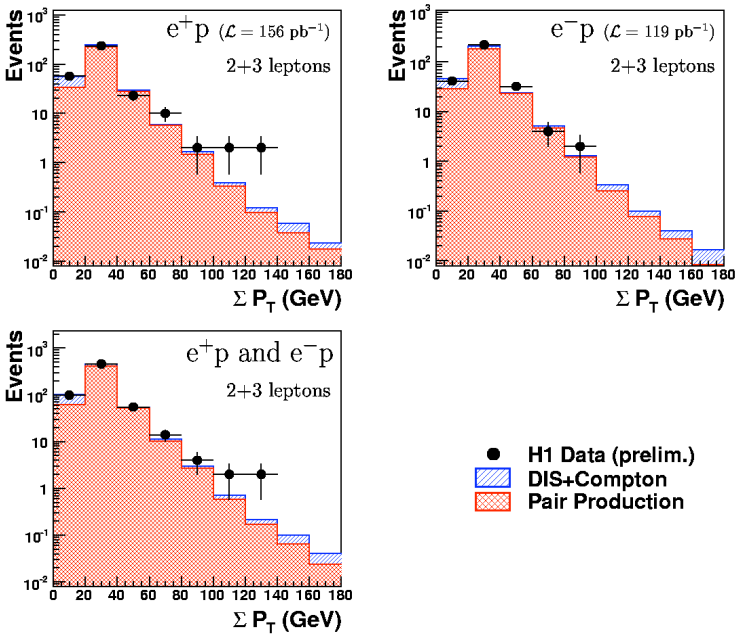

Figure 1. Distributions of the scalar sum ΣP_T of the transverse momenta of identified leptons compared to expectations for e^+p data (top left), e^-p data (top right) and combined data (bottom).

In the *ee* channel $H^{\pm\pm}$ masses below 138 GeV are excluded for a coupling h_{ee} of the electromagnetic strength, h_{ee} = 0.3. Amongst the six events at M_{ee} > 100 GeV observed in [2] only one satisfies the $H^{\pm\pm}$ selection criteria, which makes the $H^{\pm\pm}$ interpretation unlikely for these events. In the $e\mu$ (resp. $e\tau$) channel masses below 141 GeV (resp. 112 GeV) are excluded for a Yukawa coupling of 0.3. In these channels H1 significantly extends the previous excluded domains.

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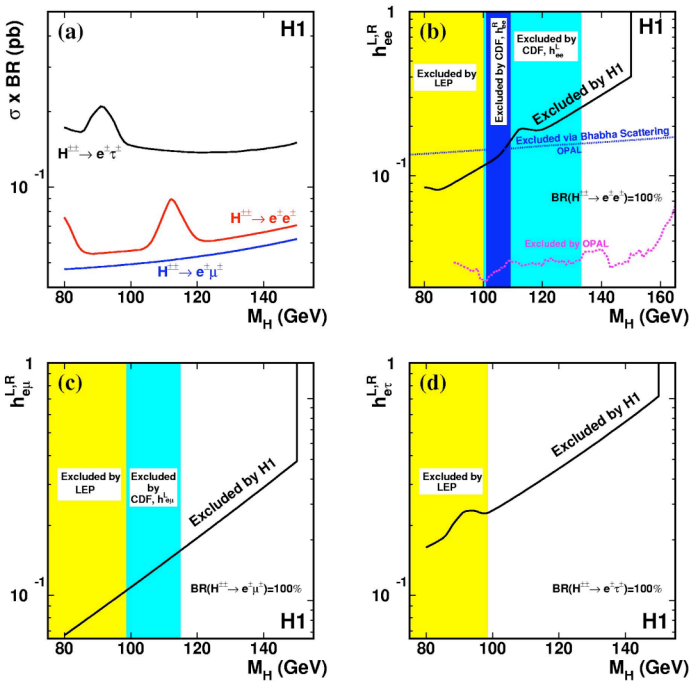

Figure 2. Upper limits at the 95% confidence level on the $H^{\pm\pm}$ production cross section times branching ratio (a), and on the couplings h_{el} assuming the $H^{\pm\pm}$ couples only to ee (b), $e\mu$ (c) or $e\tau$ (d), as a function of the $H^{\pm\pm}$ mass M_H.

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